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Numerical Simulations on Three-Dimensional Behaviors of Subducting Slabs

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Numerical models of mantle convection have been developed in order to study the effects of three-dimensionality on the formation and the dynamic behaviors of stagnant slabs. A time-dependent thermal convection of Boussinesq fluid in a three-dimensional rectangular box of 1320 km height and aspect ratio of 6:6:1 is considered. We have included both the exothermic olivine to spinel and the endothermic spinel to perovskite phase transitions at around 410 and 660 km depths from the top surface, respectively. The viscosity of mantle material is assumed to be exponentially dependent on temperature. The distribution of temperature is initially set by a half-space cooling model moving at a uniform velocity. The cold thermal boundary layer along the top surface is then divided into two sections, by introducing a ’plate boundary’ (or a ’trench axis’) running in the direction perpendicular to the surface motion. The plate subduction is imposed by applying different kinematic boundary conditions to the upstream and downstream sides of the plate boundary. The motion of the ’oceanic’ plate on the upstream side is driven by a fixed velocity at the top surface, while zero motion is set on the surface of the ’continental’ plate on the downstream side. We also included the effect of maximum yield strength in order to accommodate a strong shear deformation near the plate boundary along the top cold surface. In addition, we take into account the effect of trench migration, by assuming that the computational domain is in relative motion to the stationary mantle. Spatial mesh divisions of up to 384 by 384 in horizontal and 128 in vertical directions are utilized, by the help of the multigrid-based numerical code ACuTEMan designed for large-scale three-dimensional experiments. The three-dimensional behaviors of subducting slabs will be further discussed, by systematically studying the effects of various mechanisms, such as phase changes, viscosity stratification, trench retreat, subduction velocity and their along-axis variations.